12074/...

COMPONENT PART NOTICE

THIS PAPER IS A COMPONENT PART OF THE FOLLOWING COMPILATION REPORT:

TITLE: Computing Science and Statistics: Proceedings of the Symposium on Interface

Critical Applications of Scientific Computing (23rd): Biology, Engineering,

Medicine, Speech Held in Seattle, Washington on 21-24 April 1991.

TO ORDER THE COMPLETE COMPILATION REPORT, USE   AD-A252 938.

— THE COMPONENT PART IS PROVIDED HERE TO ALLOW USERS ACCESS TO INDIVIDUALLY
AUTHORED SECTIONS OF PROCEEDING, ANNALS, SYMPOSIA, ETC. HOWEVER, THE COMPONENT
SHOULD BE CONSIDERED WITHIN THE CONTEXT OF THE OVERALL COMPILATION REPORT AND
NOT AS A STAND-ALONE TECHNICAL REPORT.

THE FOLLOWING COMPONENT PART NUMBERS COMPRISE THE COMPILATION REPORT:

AD#: AD-P007 096   thru   AD#: AD-P007 225

AD#:   AD#:

AD#:   AD#:

DTIC
ELECTE
JUL 23 1992
S   D
A

DTIC FORM 463
MAR 85   OPI: DTIC-TID

COMPARING MATHEMATICAL AND ALGORITHMIC MODELING IN BIOLOGY

G. Arthur Mihram, Ph. D.
P. O. Box No. 1188
Princeton, NJ 08542-1188

Danielle Mihram, Ph.D.
Doheny Memorial Library
University of Southern California
Los Angeles, CA 90089

Abstract

The paper uses several examples to illustrate a distinctive difference between alternative models of biological systems: those of the mathematical vs. those of the algorithmic format. Primary among these comparisons are the models of researchers dealing with neural networks versus those of artificial intelligence [AI] researchers who predicate their work on the cognitive sciences. We show how the literature of biology itself reveals why one approach to the modelling of biological systems is more likely to succeed than the other. We compare historically the acclaimed successes of non-mathematical biologists [e.g., Darwin's ORIGIN OF THE SPECIES and Lorenz's paper, "Fashionable Fallacy of Dispensing with Description "].

We include in the paper a review of the literature dealing with the principles for conducting the design and analysis of experiments with computerised stochasic models, applicable whether their dynamics are 'controlled' within the computer mathematically or, alternatively, algorithmically. Exemplary models of AI systems are the current software packages being implemented throughout the research and university communities: viz., bibliographic retrieval programmes which, e.g., include statistical analyses for the purpose of suggesting alternative subject-search strategies.

1 Introduction

For the past four decades [since, e.g., McCulloch and Pitts (1943)], researchers in AI have become very slowly aware of the distinctive advantage which algorithmic models possess over those other computerised models of the strictly mathematical format. Quite recent authors [e.g., Amit (1989)] persist, particularly in the literature of neural networks, with their fascination with mathematical modelling, as though the success of the mathematically-expressed Newtonian models (of physics) will automatically be conferred on their own work.

On the other hand, Mihram (1973) noted that philosophers Sayre and Crosson (1963) had been struggling with the non-mathematical ("non-formalized") nature of computer programming as it might affect the modelling of mind, a mental struggle being conducted as well in the context of computerised modelling of social systems in that same decade by the mathematician Kemeny (1969).

Completely generalizing this struggle to biological systems, including not only neural networks/organs but also socio-political organizations, was the 1975 Ludwig von Bertalanffy Lecturer, J.G. Miller (1978). Miller notes that there are seven levels of living systems, from the cell to the 'supra-national society', and that at any level there are nineteen functional subsystems, the central one of which is the system's decider. Since any algorithm is a recipe for a decision-making process, Miller unknowingly [cf. Mihram (1979)] had uncovered the preference for algorithmic, as opposed to mathematical, models among biologists, sociologists, and sociobiologists as well.

2 The Algorithm

Wheatley and Unwin (1972) made quite explicit what Mihram (1970) had suggested quite strongly: viz., that algorithmic modelling is distinctly different from models written in the language of mathematics:

> An algorithm is a mathematical recipe. From this, its meaning has been extended to cover a recipe in any field of activity.
>
> Wheatley/Unwin (1972)

This distinction between the algorithm and mathematics is, however, quite grammatical [cf. Mihram (1973)]: the algorithm is a second-person expression, or command, whereas a mathematical statement is expressed in the third person (e.g., $F = mXa$).

The pertinence of the distinction to biologists, however, lies in Miller's revelation (1978) that every living system, no matter how small or complex, contains as its central subsystem its decider:

> the executive which receives information from all the other subsystems and transmits to them information outputs that control the entire organization.
>
> Miller (1978)

Thus, if one is to capture the dynamics of any living system in terms of a computerised model, one would do well to employ
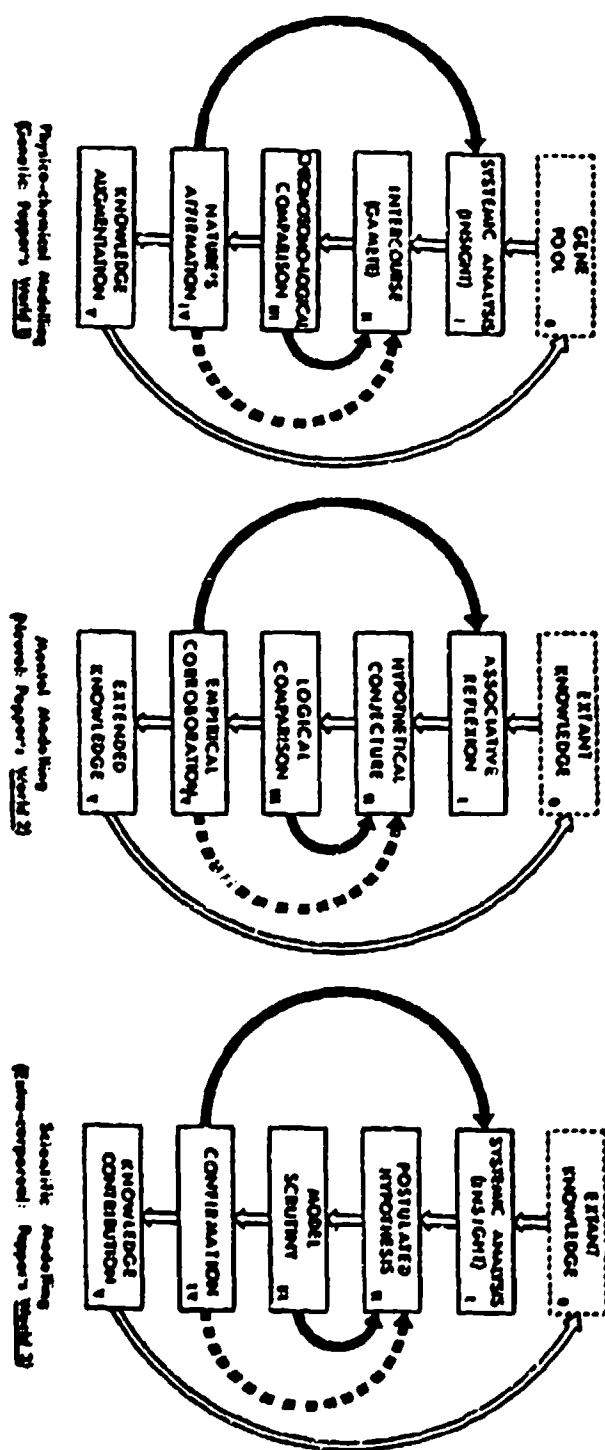
Figure 1. EVINCIBLE REASON: MAN'S SEARCH FOR TRUTH IS NATURE'S PROCESS FOR SURVIVAL.

the algorithmic (as opposed to mathematical) construction. The algorithm is ideally suited for capturing the dynamics of any living system because it can precisely describe the conditions under which a change is made, a decision or choice is enacted.

3 Exemplary Systems

Many researchers in AI take, nonetheless, the mathematical approach: e.g., researchers dealing with neural networks [cf., e.g., Newman's paper in these 1991 proceedings and Gagliano et al (1991)] express their models in mathematics, then use computer algorithms to exercise a particular solution to these mathematical relationships.

This is the same approach used by the authors (e.g., Forrester and the Meadows-es) of the once-highly-touted "world models": viz., describe the world's economic development in terms of differential, or difference, equations, then go solve (arithmetically evaluate) this 'system' of time-dependent equations on a computer [Mihram (1974a)]. Unfortunately, here the underlying algorithms mime the passage of time by: (a) computing, from the present status, the status at the next step of time; and (b) advance time by one unit; then, (c) using the same algorithms, re-compute the next status, ...

Unfortunately, such an approach fails to capture the quite erratic dynamics of any living system: one needs to write an algorithm which, like the particular living system which it describes, is activated not regularly but, rather, if and when required.

The algorithmic, as opposed to the mathematical, among computerised models is thus far better suited to capture with scientific credibility the dynamics of any living system (or, of any system containing at least one living component).

The researchers dealing with neural networks via their mathematical models typically are describing motor activities of the living system; however, artificial intelligence researchers, attempting to capture the decision-making capabilities of a living organism, are finding that the algorithm is much better suited to their task than is mathematics, notwithstanding the negativistic approach of writers like Winograd/Flores [cf. Mihram, 1989].

As a further example, consider the currently increasing use of bibliographic retrieval systems in major research libraries. These software packages, or computer programmes, are in actuality simulation models of a librarian-researcher team seeking pertinent literature citations on a specified logical combination of subjects. The models become, in effect, an AI model of a librarian or researcher at his/her task. They are not mathematical, but they do describe the reason why algorithmic models are much better suited for capturing the dynamics of any living system than is mathematics: the decisions are described precisely by algorithms, not by mathematical expressions.

4 Concluding Remarks

The history of science actually reveals that one need not use mathematics in order to qualify as a scientist. Newton may well have given mathematics an esteemed place among languages used by scientists, and the French philosophers/mathematicians/scientists of the early nineteenth century only enhanced this image [cf., e.g., Mihram, 1991] when they virtually 'institutionalized' the notion of scientific method as being no more than the theorem-proving mechanism of mathematicians.

Ampere and these other early nineteenth-century scientists were in actuality only serving to confirm the correctness of Newton's laws: they first accepted/assumed that Newton was correct, then assumed (like the geometry student in quest of the terminating 'QED') that matter is particulate in its character, and then by mathematical argumentation derived results (such as the inverse-square laws of electricity and magnetism).

However, scientists (and biologists, particularly) should recall the success (also in the nineteenth century) of Charles Darwin. His ORIGIN OF THE SPECIES, if it were not for the editorial insertion of the pagination sequence, contains virtually no mathematics. As importantly, they should heed the message of Nobel Laureate Konrad Lorenz:

> *The Fashionable Fallacy [Today] of Dispensing with Description [in Favour of Mathematics]" ...."I have never in my life published a book or a paper with either a table or a graph in it.*

<div align="center">Lorenz, 1973</div>

Scientists who convey their model of the reality which they have observed may choose a natural language (the first-person format: a la Darwin), the language of mathematics (the third-person format: a la Newton), or computer programming (the second-person format). The decision/choice must not be a mere predisposition, but, rather, a result of a reflexion [cf. Mihram and Mihram, 1984; Mihram, 1974b] on the intrinsic character of the natural phenomenon, or system of phenomena, being studied/observed. Are deciders to be mimed?

References

Amit, D.J. (1989), *World of Attractor Neural Networks*, Cambridge U. Press, London.

Gagliano, R. et al (1991), Pre- versus Post-Synaptic Long-term Potentiation in Neural Circuits, *Modeling & Simulation* 22: to appear, 1991.

Kemeny, J.G. (1969), Mathematical & Computer Models of Large Systems, *Cybernetics & the Management of Large Systems*, E.M. Dewan, ed., Amer Soc Cyber., Washington,

DC, pp. 65-74.

Lorenz, Konrad Z. (1973), Fashionable Fallacy of Dispensing with Description, *Naturwissenschaften* **60**: 1-9.

McCulloch, W. and Pitts, W. (1943), A Logical Calculus of the Ideas Immanent in Nervous Activity, *Bull. Math. Biophysics*, **5**,115-133.

Mihram, G. Arthur (1970), *Simulation: Statisucal Foundations & Methodology*, Academic Press, Orlando, FL, 1972.

Mihram, G. Arthur (1973), Simulation: Methodology for Decision Theorists, *Role & Effectiveness of Theories of Decision in Practice*, D.J. White and K.C. Bowen, eds., Hodder/ Stoughton, London, pp. 320-327, 1975.

Mihram, G. Arthur (1974a), A Critique of World Models, *Proc. SocGen Systems Research*, University Park, Cal, 1975.

Mihram, G. Arthur (1974b), *An Epistle to Dr. Benjamin Franklin*, Exposition-University Press, Pompano Beach, FL, 1975.

Mihram, G. Arthur (1979), A Simulationist's Look at Miller's LIVING SYSTEMS. *General Systems Theory: Science, Methodology, Technology*, B.R. Gaines, ed., Soc Gen Syst Res, University Park, Calif, pp. 219-229.

Mihram, G. Arthur (1989), Artificial Intelligence Research Gone Astray: The Winograd/Flores Book, *Modeling & Simulation*, **20**, 549-555.

Mihram, G. Arthur (1991), Mathematics, Statistics, Computer Programming: Simulation Methodology in Historical Perspective, *Modeling & Simulation*, **22**, to appear, 1991.

Mihram, G. Arthur and Danielle Mihram (1984), Credibility: Every Computer Programme is a Simulation Model, *Proc 18th Ann Hawaii Int'l Conf on System Sciences*, Honolulu, 306-316,1985.

Miller, J.G. (1978), *Living Systems*, McGraw-Hill, N.Y.

Sayre, K.M. and Crosson, F.J., eds. (1963), *The Modeling of Mind*, Simon & Schuster, N.Y.

Wheatley, D.M. and Unwin, A.W. (172), *Algorithm User's Guide*, Longman, London.